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(54) **POSITRON EMISSION COMPUTED TOMOGRAPHY APPARATUS AND IMAGE PROCESSING APPARATUS**

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G01T 1/29 (2006.01)
G01T 1/164 (2006.01)
A61B 6/03 (2006.01)

(52) **U.S. Cl.**
CPC ***G01T 1/2985*** (2013.01); ***A61B 6/037*** (2013.01); ***G01T 1/1647*** (2013.01)

(58) **Field of Classification Search**
CPC A61B 6/032; A61B 6/037; A61B 6/541; G01T 1/2985; G01T 1/1647
USPC 600/428; 382/107
See application file for complete search history.

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(57) **ABSTRACT**

A positron emission computed tomography apparatus according to an embodiment includes a detector, a coincidence counting information generating unit, and a body movement detecting unit. The detector detects annihilation radiation released from a subject. The coincidence counting information generating unit searches for sets of counting information, which counted a pair of annihilation radiations at substantially the same time, from a counting information list that is generated from output signals of the detector; generates a set of coincidence counting information for each retrieved set of counting information; and generates a time series list of coincidence counting information. Based on the time series list of coincidence counting information, the body movement detecting unit detects temporal changes in the body movement of the subject.

9 Claims, 7 Drawing Sheets

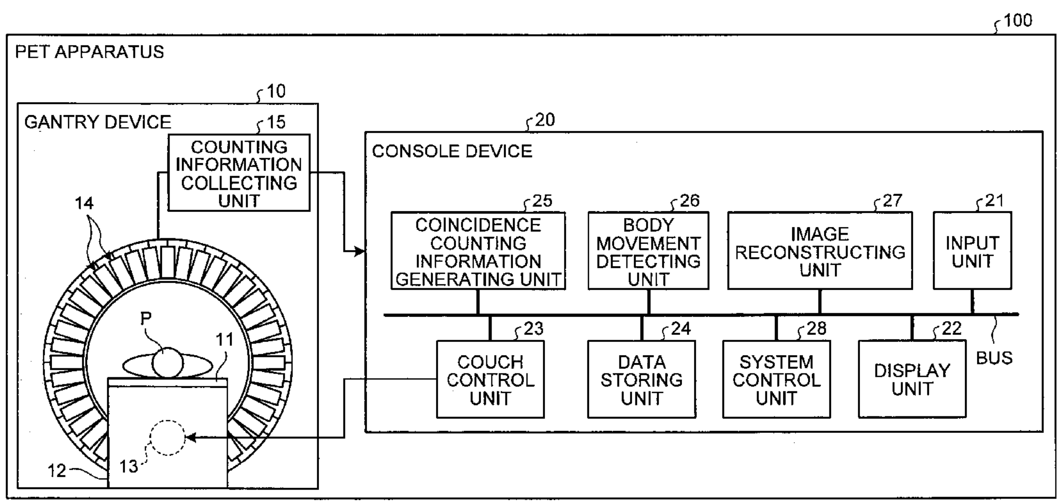


FIG.1

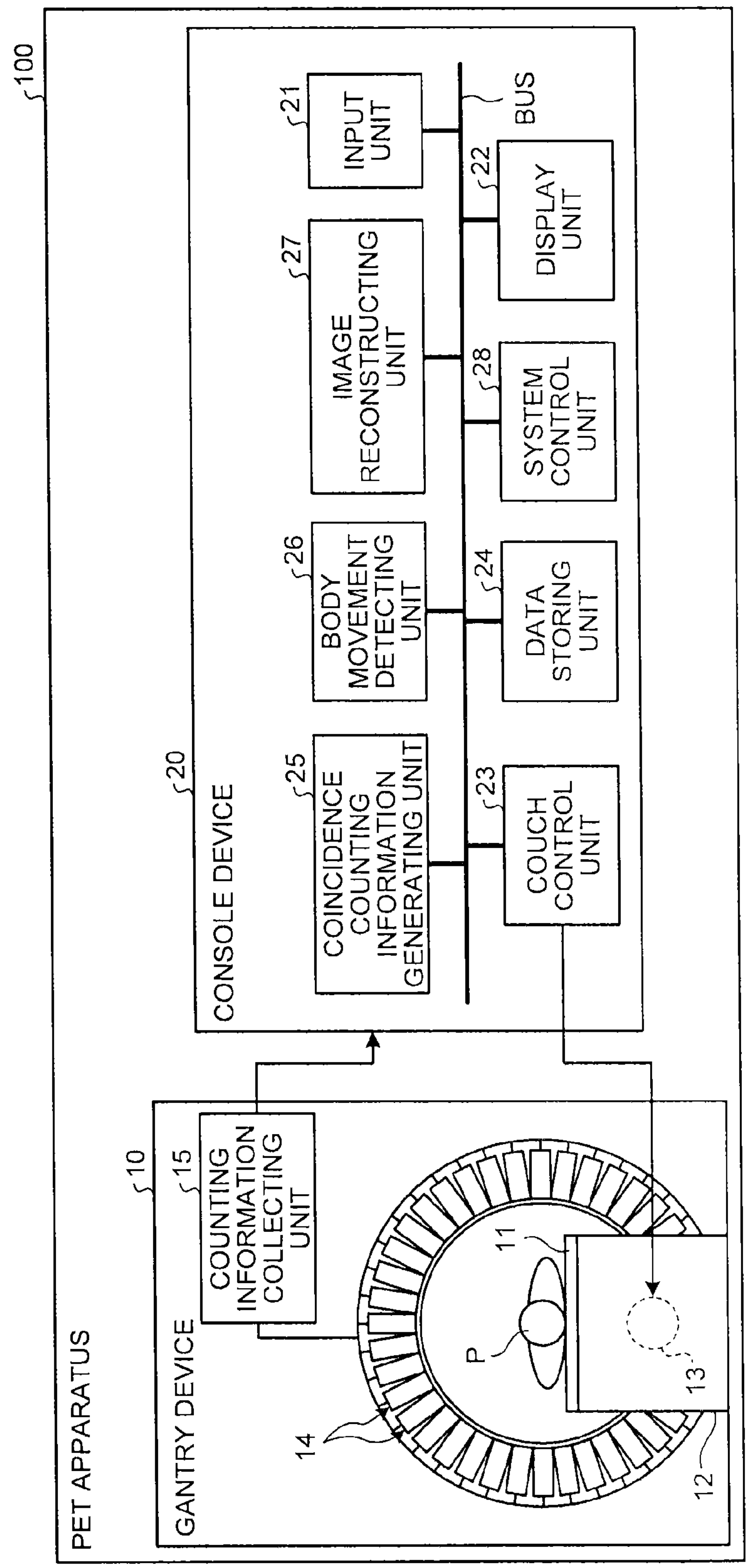

100
PET APPARATUS
10
GANTRY DEVICE
15
COUNTING INFORMATION COLLECTING UNIT
11
12
13
14
P
20
CONSOLE DEVICE
21
INPUT UNIT
BUS
22
DISPLAY UNIT
27
IMAGE RECONSTRUCTING UNIT
28
SYSTEM CONTROL UNIT
26
BODY MOVEMENT DETECTING UNIT
24
DATA STORING UNIT
25
COINCIDENCE COUNTING INFORMATION GENERATING UNIT
23
COUCH CONTROL UNIT

FIG.2

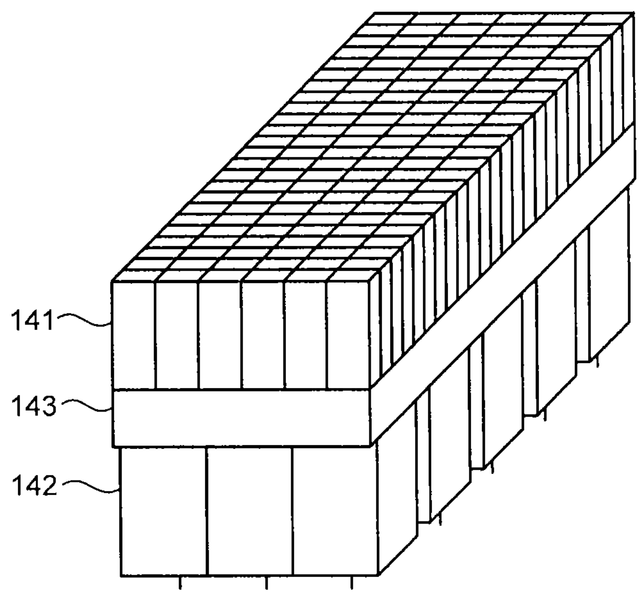

141
143
142

FIG.3

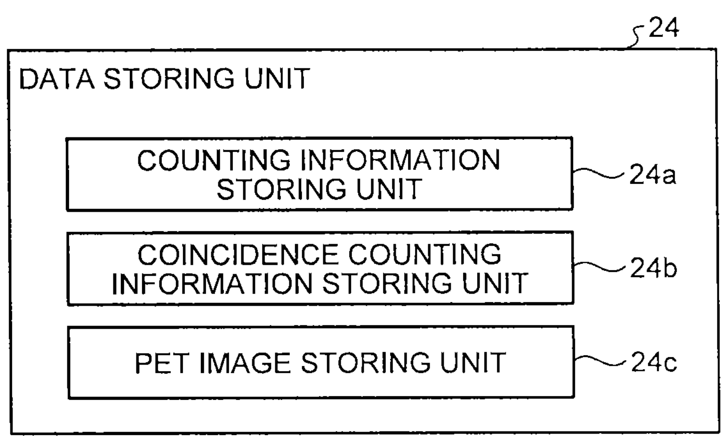

24
DATA STORING UNIT
COUNTING INFORMATION STORING UNIT
24a
COINCIDENCE COUNTING INFORMATION STORING UNIT
24b
PET IMAGE STORING UNIT
24c

FIG.4

MODULE ID	SCINTILLATOR NUMBER (P)	ENERGY VALUE (E)	DETECTION TIME (T)
D1	P11	E11	T11
	P12	E12	T12
	P13	E13	T13
	⋮	⋮	⋮

MODULE ID	SCINTILLATOR NUMBER (P)	ENERGY VALUE (E)	DETECTION TIME (T)
D2	P21	E21	T21
	P22	E22	T22
	P23	E23	T23
	⋮	⋮	⋮

MODULE ID	SCINTILLATOR NUMBER (P)	ENERGY VALUE (E)	DETECTION TIME (T)
D3	P31	E31	T31
	P32	E32	T32
	P33	E33	T33
	⋮	⋮	⋮

⋮

FIG.5

COINCIDENCE NO.	SCINTILLATOR NUMBER (P)	ENERGY VALUE (E)	DETECTION TIME (T)	SCINTILLATOR NUMBER (P)	ENERGY VALUE (E)	DETECTION TIME (T)
1	P11	E11	T11	P22	E22	T22
2	P12	E12	T12	P32	E32	T32
3	P13	E13	T13	P33	E33	T33
⋮	⋮	⋮	⋮	⋮	⋮	⋮

FIG.6

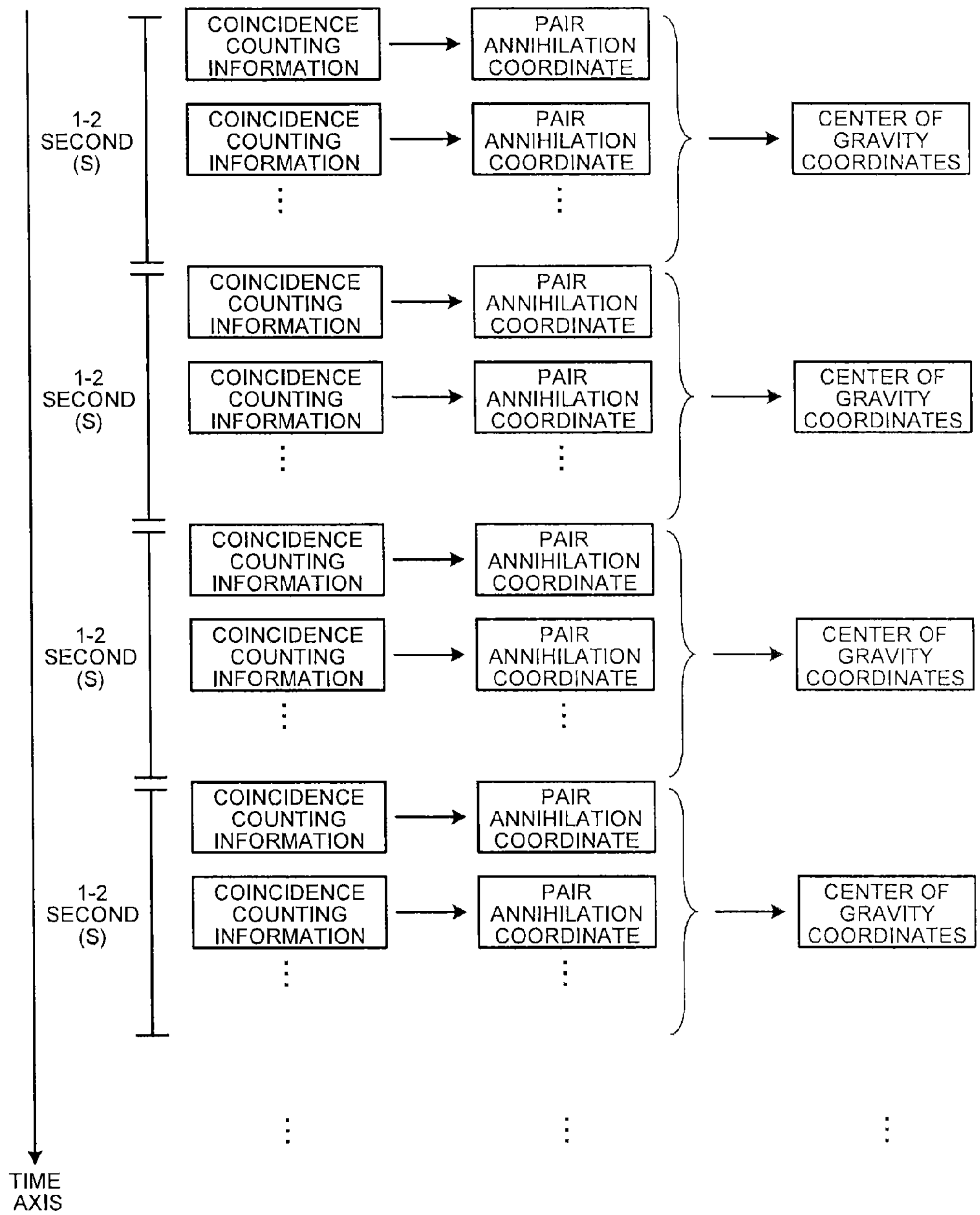

1-2 SECOND (S)
COINCIDENCE COUNTING INFORMATION
PAIR ANNIHILATION COORDINATE
CENTER OF GRAVITY COORDINATES
TIME AXIS

FIG.7

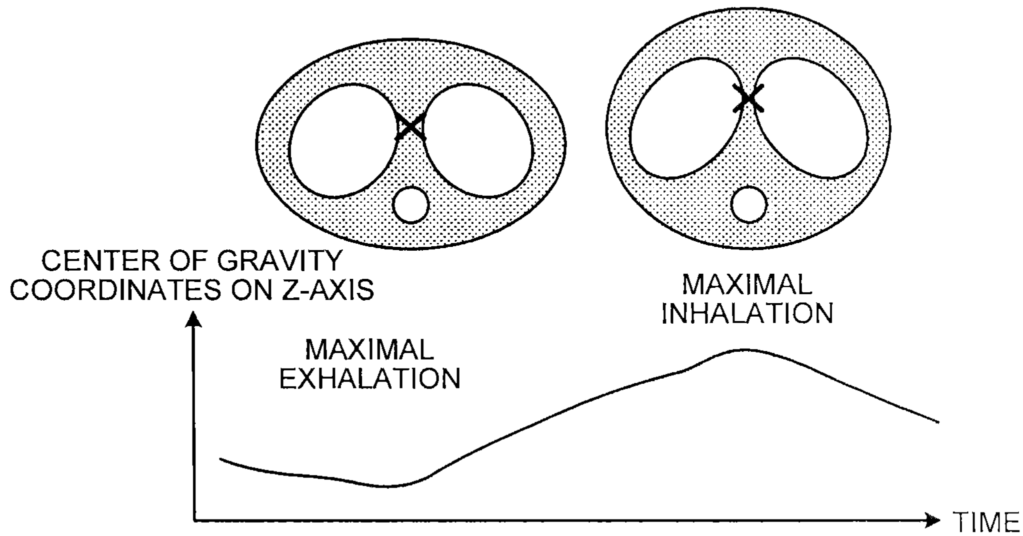

CENTER OF GRAVITY
COORDINATES ON Z-AXIS
MAXIMAL
INHALATION
MAXIMAL
EXHALATION
TIME

FIG.8

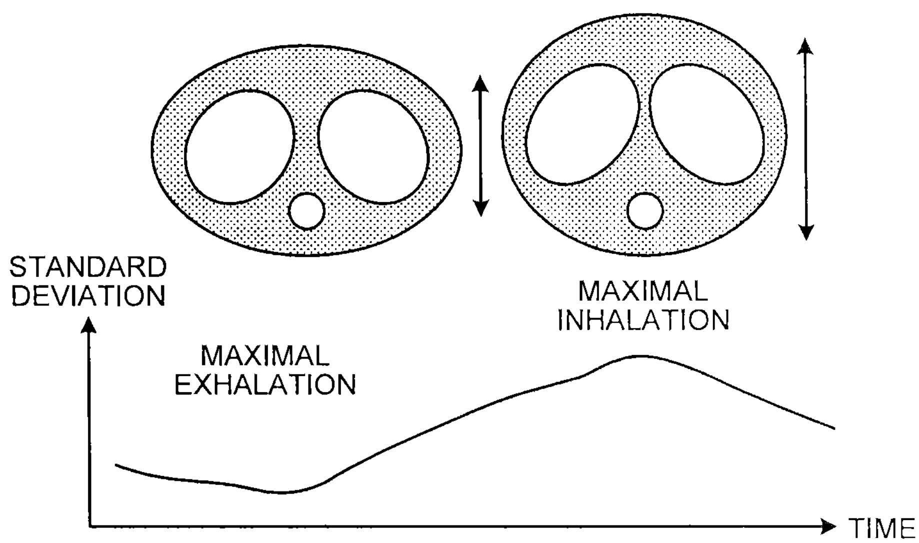
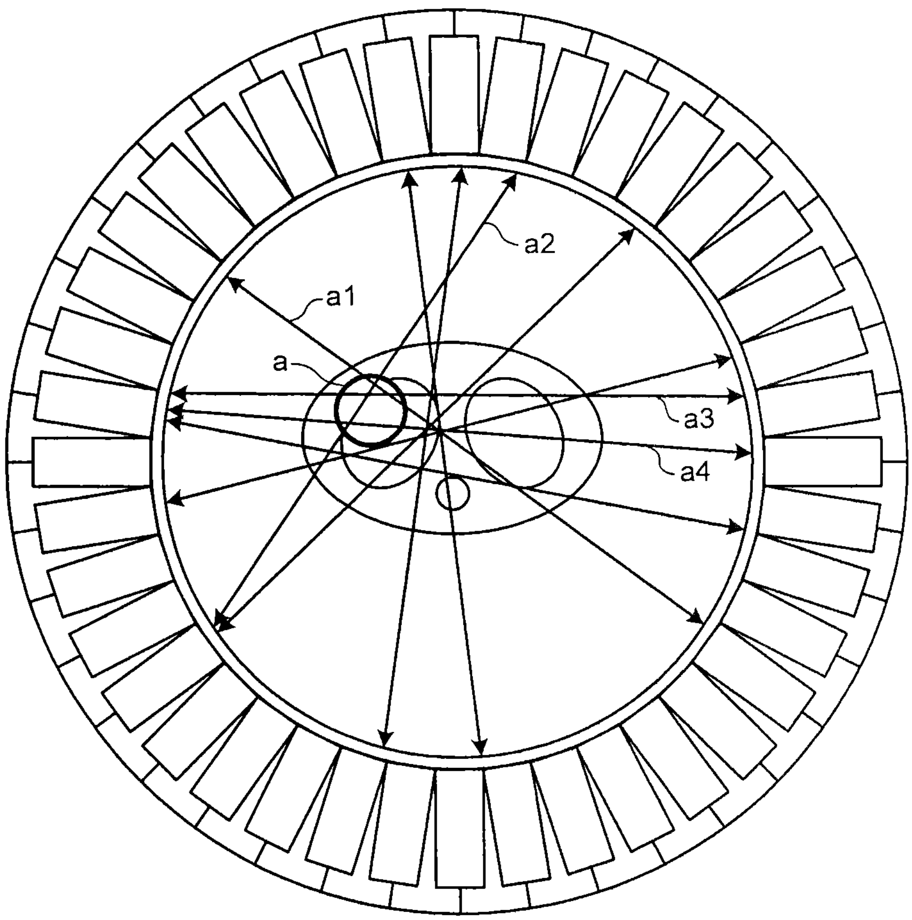

STANDARD
DEVIATION
MAXIMAL
INHALATION
MAXIMAL
EXHALATION
TIME

FIG.9



POSITRON EMISSION COMPUTED TOMOGRAPHY APPARATUS AND IMAGE PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2011-262756, filed on Nov. 30, 2011; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a positron emission computed tomography apparatus and an image processing apparatus.

BACKGROUND

Typically, as a nuclear medicinal imaging apparatus, a positron emission computed tomography (PET) apparatus is known. During the imaging performed by a PET apparatus, a radiopharmaceutical agent that is labeled with positron-emitting radionuclides is administered to the subject. As a result, the positron-emitting radionuclides that are selectively incorporated into the body tissues of the subject release positrons, which then get coupled with electrons and are annihilated. At that time, the positrons release pairs of annihilation radiations (hereinafter, referred to as "annihilation gamma-rays) in the direction almost opposite. The PET apparatus detects such annihilation gamma-rays with the use of detectors that are arranged in a ring-like manner around the subject. Then, by referring to the detection result, the PET apparatus generates a time series list (also called "coincidence list") of coincidence counting information. Subsequently, with the use of the time series list of coincidence counting information, the PET apparatus performs reconstruction and generates a PET image.

Meanwhile, the methods of imaging performed by a PET apparatus include imaging in synchronization with the respiration of the subject. During the respiration-synchronized imaging, an external device other than the main body of the PET apparatus is used to obtain body movement information of the subject. The external device is, for example, a respiratory displacement monitor. Herein, for example, during the imaging, the respiratory displacement monitor emits infrared light to an infrared light reflection marker that is placed on the chest region of the subject; takes photographs using a reflection camera; and traces the marker shadow to obtain information on respiratory displacement. However, in the case of using such an external device, it becomes necessary to separately setup and adjust the external device. Moreover, since the infrared light reflection marker may move out of alignment or may fall down during the imaging, using it can be a complicated task.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a configuration of a PET apparatus according to a first embodiment;

FIG. **2** is a diagram for explaining detector modules according to the first embodiment;

FIG. **3** is a diagram for explaining a data storing unit according to the first embodiment;

FIG. **4** is a diagram for explaining a list of sets of counting information according to the first embodiment;

FIG. **5** is a diagram for explaining a time series list of coincidence counting information according to the first embodiment;

FIG. **6** is a diagram for explaining a body movement detecting unit according to the first embodiment;

FIG. **7** is a diagram for explaining the body movement detecting unit according to the first embodiment;

FIG. **8** is a diagram for explaining the body movement detecting unit according to a modification example of the first embodiment; and

FIG. **9** is a diagram for explaining the body movement detecting unit according to a second embodiment.

DETAILED DESCRIPTION

Exemplary embodiments of a positron emission computed tomography apparatus and an image processing apparatus are described below in detail with reference to the accompanying drawings.

First Embodiment

In a first embodiment, a PET apparatus **100** does not make use of an external device such as a respiratory displacement monitor. Instead, the PET apparatus **100** obtains body movement information of the subject by means of direct processing for detection data. More particularly, from each set of coincidence counting information specified in a time series list of coincidence counting information, the PET apparatus **100** according to the first embodiment calculates each pair annihilation coordinate with the use of time of flight (TOF) information; and detects the temporal changes in the body movement of the subject based on the pair annihilation coordinates.

Herein, the body movement is detected by a body movement detecting unit **26** (described later). In the following description, firstly, a configuration of the PET apparatus **100** according to the first embodiment is explained; and that is followed by a detailed explanation of the operations performed by the body movement detecting unit **26**.

FIG. **1** is a block diagram illustrating a configuration of the PET apparatus **100** according to the first embodiment. As illustrated in FIG. **1**, the PET apparatus **100** according to the first embodiment includes a gantry device **10** and a console device **20**.

The gantry device **10** detects pairs of annihilation gamma-rays, which are released from the positrons present inside a subject P, with the use of detectors that are arranged in a ring-like manner around the subject P. Then, the gantry device **10** generates counting information from the output signals of the detector and collects the counting information. As illustrated in FIG. **1**, the gantry device **10** includes a couch top **11**, a couch **12**, a couch driving unit **13**, a plurality of detector modules **14**, and a counting information collecting unit **15**. Moreover, as illustrated in FIG. **1**, the gantry device **10** has a cavity that serves as a imaging region.

The couch top **11** is a bed on which the subject P is made to lie down. The couch top **11** is disposed on top of the couch **12**. The couch driving unit **13** moves the couch top **11** under the control of a couch control unit **23** (described later). For example, the couch driving unit **13** moves the couch top **11** in such a way that the subject P moves in the imaging region of the gantry device **10**.

The detector modules **14** detect the annihilation gamma-rays that are released from the positrons present inside the subject P. As illustrated in FIG. **1**, the detector modules **14** are disposed to surround the subject P in a ring-like manner.

FIG. **2** is a diagram for explaining the detector modules **14** according to the first embodiment. As illustrated in FIG. **2**, each detector module **14** is an Anger-type detector that implements the photon counting method, and includes scintillators **141**, photomultiplier tubes (PMTs) **142**, and a light guide **143**.

The scintillators **141** convert the incident annihilation gamma-rays, which released from the positrons present inside the subject P, into scintillation photons (optical photons); and then output that. The scintillators **141** are formed with scintillator crystals suitable for TOF such as lanthanum bromide (LaBr3), lutetium yttrium oxyorthosilicate (LYSO), lutetium oxyorthosilicate (LSO), or lutetium gadolinium oxyorthosilicate (LGSO). As illustrated in FIG. **2**, the scintillators **141** are arranged in a two-dimensional manner. The photomultiplier tubes **142** multiply the scintillation photons output from the scintillators **141** and convert it into electric signals. As illustrated in FIG. **2**, a plurality of photomultiplier tubes **142** is arranged. The light guide **143** transmits the scintillation photons, which is output from the scintillators **141**, to the photomultiplier tubes **142**. The light guide **143** is, made of, for example, a plastic material having superior light permeability.

Each photomultiplier tube **142** includes a photocathode that receives scintillation photons and generates photoelectrons; a multi-stage dynode that applies an electric field so as to accelerate the photoelectrons; and an anode through which electrons outflow. The electrons that are released from the photocathode due to a photoelectric effect accelerate toward the dynode, collide with the surface of the dynode, and beat out a plurality of electrons. When this phenomenon is repeated across the multiple stages of the dynode; the number of electrons gets multiplied because of a chain-reaction-like manner, and the number of electrons in the anode reaches to about one million. Thus, in this example, the gain factor of each photomultiplier tube **142** becomes millionfold. Moreover, due to the multiplication in a chain-reaction-like manner, usually a voltage of 1000 volts or more gets applied between the dynode and the anode.

In this way, in the detector modules **14**, the annihilation gamma-rays, which are released from the positrons present inside the subject P, are converted into scintillation photons by the scintillators **141**; and the scintillator light is converted into electric signals by the photomultiplier tubes **142**. With that, the detector modules **14** detect the annihilation gamma-rays released from the subject P.

Returning to the explanation with reference to FIG. **1**, the counting information collecting unit **15** generates counting information from the output signals of the detector modules **14** and stores the counting information in a data storing unit **24** (described later). Meanwhile, although not illustrated in FIG. **1**, the detector modules **14** are divided into a plurality of blocks, and the counting information collecting units **15** are disposed on a block-by-block basis. For example, in the first embodiment, since a single detector module **14** is considered to be a single block, the counting information collecting units **15** is disposed with respect to each detector module **14**.

The counting information collecting unit **15** converts the output signals of the detector modules **14** into digital data and generates counting information. Herein, the counting information contains the detected positions, energy values, and detection time of the annihilation gamma-rays. For example, the counting information collecting unit **15** identifies a plurality of photomultiplier tubes **142** that have concurrently converted the scintillation photons into electric signals. Then, the counting information collecting unit **15** refers to the position of each identified photomultiplier tube **142** and the intensity of electric signals and accordingly calculates the position of the center of gravity; and then identifies scintillator numbers (P) that indicate the positions of the scintillators **141** on which the annihilation gamma-rays incident had occurred. Meanwhile, if the photomultiplier tubes **142** are capable of detecting positions, then the position identification can be performed by the photomultiplier tubes **142**.

Moreover, the counting information collecting unit **15** performs integral calculation with respect to the intensity of electric signals that are output from each photomultiplier tube **142**, and identifies energy values (E) of the incident annihilation gamma-rays on the detector modules **14**. Furthermore, the counting information collecting unit **15** identifies detection times (T) taken for the detection of the annihilation gamma-rays by the detector modules **14**. For example, the counting information collecting unit **15** identifies the detection times (T) with accuracy in the unit of 10^{-12} seconds (i.e., a picosecond). Herein, the detection times (T) can either be an absolute time or be the elapsed time since the start of imaging. In this way, the counting information collecting unit **15** generates counting information that contains the scintillator numbers (P), the energy values (E), and the detection times (T).

The console device **20** receives an operation performed by an operator with respect to the PET apparatus **100**, and controls imaging of PET images as well as reconstructs the PET images with the use of the counting information collected by the gantry device **10**. As illustrated in FIG. **1**, the console device **20** includes an input unit **21**, a display unit **22**, the couch control unit **23**, the data storing unit **24**, a coincidence counting information generating unit **25**, the body movement detecting unit **26**, an image reconstructing unit **27**, and a system control unit **28**. Herein, the constituent elements of the console device **20** are interconnected via a bus.

The input unit **21** is a mouse or a keyboard that is used by the operator of the PET apparatus **100** to input various instructions and various settings. Then, the input unit **21** transfers the various instructions and the various settings to the system control unit **28**. For example, the input unit **21** is used to receive an imaging start instruction. The display unit **22** is a monitor that is viewed by the operator, that displays a respiratory waveform of the subject and PET images, and that displays a graphical user interface (GUI) which enables the operator to input various instructions and various settings. The couch control unit **23** controls the couch driving unit **13**.

The data storing unit **24** is used to store a variety of data used in the PET apparatus **100**. FIG. **3** is a diagram for explaining the data storing unit **24** according to the first embodiment. As illustrated in FIG. **3**, the data storing unit **24** includes a counting information storing unit **24***a*, a coincidence counting information storing unit **24***b*, and a PET image storing unit **24***c*. Herein, the data storing unit **24** is configured with, for example, a semiconductor memory such as a random access memory (RAM) or a flash memory, or with a hard disk or an optical disk.

The counting information storing unit **24***a* is used to store the counting information that is collected by each counting information collecting unit **15**. Herein, a list of sets of counting information that is stored in the counting information storing unit **24***a* is used during the operations performed by the coincidence counting information generating unit **25**. Meanwhile, the list of sets of counting information that is stored in the counting information storing unit **24***a* can either be deleted after being used during the operations performed by the coincidence counting information generating unit **25** or be kept stored for a predetermined amount of time.

FIG. **4** is a diagram for explaining the list of sets of counting information according to the first embodiment. As illustrated in FIG. **4**, in the counting information storing unit **24***a*, the sets of counting information each containing the scintillator numbers (P), the energy values (E), and the detection times (T) are stored in a corresponding manner to module IDs that are used in identifying the detector modules **14**.

The coincidence counting information storing unit **24***b* is used to store a time series list of coincidence counting information that is generated by the coincidence counting information generating unit **25**. The time series list of coincidence counting information stored in the coincidence counting information storing unit **24***b* is used during the operations performed by the body movement detecting unit **26** and the image reconstructing unit **27**. Meanwhile, the time series list of coincidence counting information stored in the coincidence counting information storing unit **24***b* can either be deleted after being used during the operations performed by the image reconstructing unit **27** or be kept stored for a predetermined amount of time.

FIG. **5** is a diagram for explaining the time series list of coincidence counting information according to the first embodiment. As illustrated in FIG. **5**, in the coincidence counting information storing unit **24***b*; sets of the counting information are stored in a corresponding manner to coincidence numbers that represent the serial numbers of the sets of coincidence counting information. In the first embodiment, the time series list of coincidence counting information is arranged roughly in the chronological order based on the detection times (T) of the sets of counting information.

The PET image storing unit **24***c* is used to store PET images that have been reconstructed by the image reconstructing unit **27**. The PET images stored in the PET image storing unit **24***c* are displayed on the display unit **22** by the system control unit **28**.

Returning to the explanation with reference to FIG. **1**, the coincidence counting information generating unit **25** makes use of the list of sets of counting information counting information collected by the counting information collecting unit **15** and generates a time series list of coincidence counting information. More particularly, based on the detection times (T) of the sets of counting information, the coincidence counting information generating unit **25** searches for such sets of counting information, from the list of sets of counting information stored in the counting information storing unit **24***a*, which substantially concurrently counted the pairs of annihilation gamma-rays. Moreover, the coincidence counting information generating unit **25** generates a set of coincidence counting information for each set of counting information that has been retrieved, and then stores the generated sets of coincidence counting information roughly in the chronological order in the coincidence counting information storing unit **24***b*.

For example, the coincidence counting information generating unit **25** generates the coincidence counting information based on a coincidence counting information generating condition that is input by the operator. The coincidence counting information generating condition includes specification of a time window width. For example, the coincidence counting information generating unit **25** generates the coincidence counting information based on a time window width.

For example, the coincidence counting information generating unit **25** refers to the counting information storing unit **24***a* and, among the detector modules **14**, searches for a set of counting information which has the time lag of the detection times (T) within the time window width. For example, assume that the coincidence counting information generating unit **25** retrieves sets "P**11**, E**11**, T**11**" and "P**22**, E**22**, T**22**" as the set that satisfies the coincidence counting information generating condition. In that case, the coincidence counting information generating unit **25** generates that set as the coincidence counting information and stores it in the coincidence counting information storing unit **24***b*. Meanwhile, the coincidence counting information generating unit **25** can generate the coincidence counting information with the use of an energy window width along with the time window width.

The body movement detecting unit **26** detects the temporal changes in the body movement of the subject P based on the time series list of the coincidence counting information generated by the coincidence counting information generating unit **25**. The operations performed by the body movement detecting unit **26** are explained later in detail.

The image reconstructing unit **27** reconstructs PET images. More particularly, the image reconstructing unit **27** reads the time series list of coincidence counting information, which is stored in the coincidence counting information storing unit **24***b*, and performs reconstruction of a PET image. Then, the image reconstructing unit **27** stores the reconstructed PET image in the PET image storing unit **24***c*.

Meanwhile, the image reconstructing unit **27** can reconstruct PET images also by using the temporal changes in the body movement that are detected by the body movement detecting unit **26**. In that case, for example, the image reconstructing unit analyzes the respiration cycle of the subject P from the temporal changes in the body movement that are detected by the body movement detecting unit **26** and, according to the respiration cycle, partitions the time series list of coincidence counting information into a plurality of phases (for example, partitions a single respiration cycle into 6 phases). Then, the image reconstructing unit **27** refers to the coincidence counting information included in each phase and reconstructs a PET image on a phase-by-phase basis. Herein, it is believed that, in each phase, the body movement of the subject is only small in amount. Thus, a single PET image is reconstructed using only such coincidence counting information that is not much affected by the body movement. That contributes to the enhancement in the image quality of PET images.

The system control unit **28** controls the PET apparatus **100** in entirety by controlling the gantry device **10** and the console device **20**. For example, the system control unit **28** controls the imaging performed by the PET apparatus **100**. Meanwhile, each of the coincidence counting information generating unit **25**, the body movement detecting unit **26**, the image reconstructing unit **27**, and the system control unit **28** is configured with an integrated circuit such as an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA), or with an electronic circuit such a central processing unit (CPU) or a micro processing unit (MPU).

Detection of Body Movement According to First Embodiment

Given below is the explanation regarding the detection of body movement according to the first embodiment. As described above, according to the first embodiment, based on the time series list of coincidence counting information, the body movement detecting unit **26** detects the temporal changes in the body movement of the subject P. More particularly, from each set of coincidence counting information specified in the time series list of coincidence counting information, the body movement detecting unit **26** calculates each pair annihilation coordinate on a line of response (LOR) and detects the temporal changes in the body movement of the subject P based on the calculated pair annihilation coordinates.

FIG. **6** and FIG. **7** are diagrams for explaining the body movement detecting unit **26** according to the first embodiment. In FIG. **6**, the sets of coincidence counting information that are arranged roughly in the chronological order are illustrated on a conceptual basis. For example, as illustrated in FIG. **6**, the body movement detecting unit **26** partitions the time series list of coincidence counting information at predetermined time intervals (hereinafter, referred to as "frames"). In the case of obtaining respiratory phases as the temporal changes in the body movement, it is desirable that the frames are shorter than the respiration cycle of the subject P but longer than the cardiac cycle. For example, the frames are of about 1 or 2 seconds.

Then, for each predetermined frame, the body movement detecting unit **26** calculates each pair annihilation coordinate on an LOR from each set of coincidence counting information included in that frame; and accordingly calculates the average of pair annihilation coordinates (i.e., the center of gravity coordinates of the distribution of pair annihilation coordinates). Herein, the body movement detecting unit **26** calculates the pair annihilation coordinates using the TOF information. That is, the body movement detecting unit **26** calculates the detection time lag from a single set of counting information included in the coincidence counting information, and calculates pair annihilation coordinates as spatial positions of positrons on an LOR using the detection time lag. Herein, an LOR is a line that joins a set of detection positions corresponding to a pair of annihilation gamma-rays.

Then, the body movement detecting unit **26** calculates the center of gravity coordinates of the distribution of pair annihilation coordinates in each frame, and detects the temporal changes in the center of gravity coordinates. For example, of the center of gravity coordinates (x-coordinate, y-coordinate, z-coordinate) of pair annihilation coordinates, the body movement detecting unit **26** selects the coordinate axis having the largest temporal changes and plots the center of gravity coordinates on the selected coordinate axis so as to obtain the respiratory phases. For example, the body movement detecting unit **26** selects the center of gravity coordinates on the z-axis. Then, on a graph having time as the horizontal axis and having center of gravity coordinates as the vertical axis as illustrated in FIG. **7**; the body movement detecting unit **26** plots, along the time axis, the center of gravity coordinates on the z-axis that are calculated for each frame. As a result, as illustrated in FIG. **7**, the respiratory waveform of the subject P gets drawn on the graph. Meanwhile, in FIG. **7**, schematic diagrams illustrated above the graph represent cross-sectional schematic diagrams of the chest region of the subject P. The "x" marks represent the center of gravity coordinates in the z-axis in the case of maximal exhalation and the center of gravity coordinates in the z-axis in the case of maximal inhalation. Meanwhile, for example, the graph illustrated in FIG. **7** can be displayed on the display unit **22** or be used in internal calculations.

It is described above that, of the center of gravity coordinates (x-coordinate, y-coordinate, z-coordinate) of pair annihilation coordinates, the body movement detecting unit **26** selects the coordinate axis having the largest temporal changes. However, that is not the only possible case. For example, the body movement detecting unit **26** identifies the direction having the largest temporal changes, sets a new coordinate axis oriented in the identified direction, and plots the center of gravity coordinates on the new coordinate axis so as to obtain the respiratory phases.

As described above, according to the first embodiment, the body movement information of the subject is obtained by means of direct processing for detection data. As a result, the body movement information of the subject can be obtained without difficulty. Moreover, since the body movement information is included in the detection data, it is possible to use it as may be necessary. For example, the body movement information can be used in multiple analyses.

Modification Example of First Embodiment

In the first embodiment, the explanation is given for an example in which the body movement detecting unit **26** calculates the average of pair annihilation coordinates (i.e., calculates the center of gravity coordinates) from a plurality of pair annihilation coordinates. However, that is not the only possible case. Alternatively, for example, as the statistic, the body movement detecting unit **26** can calculate the standard variation of the pair annihilation coordinates.

FIG. **8** is a diagram for explaining the body movement detecting unit according to a modification example of the first embodiment. The body movement detecting unit **26** calculates, for each predetermined frame, each pair annihilation coordinate on an LOR from each set of coincidence counting information included in that frame; and then calculates the standard deviation of the distribution of pair annihilation coordinates from a plurality of pair annihilation coordinates that are calculated. Herein, standard deviation points to the spread of a plurality of pair annihilation coordinates included in a frame (see an arrow illustrated in FIG. **8**). The body movement detecting unit **26** calculates the standard deviation of pair annihilation coordinates for all frames; and plots the standard deviations along the time axis so as to obtain the respiratory phases. For example, on a graph having time as the horizontal axis and having standard deviation as the vertical axis as illustrated in FIG. **8**, the body movement detecting unit **26** plots the standard deviations on the z-axis that are calculated for all frames. As a result, as illustrated in FIG. **8**, the respiratory waveform of the subject P gets drawn on the graph.

Second Embodiment

Given below is the explanation of a second embodiment. In the first embodiment, the explanation is given for a method in which the temporal changes in the body movement are detected with the use of all sets of coincidence counting information included in the time series list of coincidence counting information. However, that is not the only possible case. In the second embodiment, the explanation is given for a method in which the temporal changes in the body movement are detected with the use of only some of the sets of coincidence counting information.

FIG. **9** is a diagram for explaining the body movement detecting unit **26** according to the second embodiment. FIG. **9** is a schematic diagram of a cross-sectional surface of the chest region of the subject P that is surrounded by detectors. A black circle "a" represents the heart of the subject P. In the second embodiment, the cardiac phases are obtained as the temporal changes in the body movement.

For example, from the time series list of coincidence counting information, the body movement detecting unit **26** selects only such a plurality of sets of coincidence counting information for each of which the LOR passes through the heart of the subject P. Herein, by referring to the posture of the subject P who is lying down on the couch top **11** or by referring to the body type of the subject P, it is possible to roughly identify in advance the LORs (i.e., the sets of detection positions) that pass through the heart. Hence, from the time series list of coincidence counting information, the body movement detecting unit **26** selects only the coincidence counting information that corresponds to the detection positions of the sets of detection positions identified in advance. For example, in FIG. **9**, LORs a**1** to a**4** pass through the heart.

Then, from each selected set of coincidence counting information, the body movement detecting unit **26** calculates each pair annihilation coordinate on each LOR and, in an identical manner to the first embodiment, detects the temporal changes in the body movement of the subject P based on the plurality of pair annihilation coordinates that are calculated.

Modification Example of Second Embodiment

As a modification example of the second embodiment, for example, the explanation is given about a technique in which the respiratory phases are obtained as the temporal changes in the body movement, while the effect of the cardiac phases is eliminated. In the first embodiment, the explanation is given regarding the case in which the respiratory phase can be obtained as the temporal changes in the body movement. However, in case the radiopharmaceutical agent gets accumulated in the heart, there is a possibility that the effect of the cardiac phases gets reflected in the temporal changes in the body movement. In that case, on the respiratory waveform representing the respiratory phases, a waveform that represents the cardiac phases having a shorter cycle than the respiration cycle appears as noise.

In that regard, for example, from the time series list of coincidence counting information, the body movement detecting unit **26** selects only such a plurality of sets of coincidence counting information for each of which the LOR does not pass through the heart of the subject P. That is, from the time series list of coincidence counting information, the body movement detecting unit **26** excludes the coincidence counting information corresponding to the sets of detection positions identified in advance as the LORs passing through the heart, and selects the remaining coincidence counting information. For example, in FIG. **9**, LORs other than the LORs a**1** to a**4** do not pass through the heart.

Then, from each selected set of coincidence counting information, the body movement detecting unit **26** calculates each pair annihilation coordinate on each LOR and, in an identical manner to the first embodiment, detects the temporal changes in the body movement of the subject P based on a plurality of pair annihilation coordinates that are calculated.

As described above, according to the second embodiment, the temporal changes in the body movement are detected by selecting only some of the coincidence counting information. As a result, it becomes possible to detect the temporal changes in the body movement by focusing attention on a particular body part or to detect the temporal changes in the body movement by eliminating the effect of a particular body part.

Other Embodiments

In the embodiments described above, the PET apparatus **100** is assumed to have the configuration illustrated in FIG. **1**. However, that is not the only possible configuration. Alternatively, for example, the counting information collecting unit **15** can be disposed in the console device **20**. Conversely, the coincidence counting information generating unit **25** can be disposed in the gantry device **10**. Moreover, the variety of data stored in the data storing unit **24** can either be held in the gantry device **10** or be held in the console device **20**. Meanwhile, each type of data can be held in the PET apparatus **100** for an arbitrary period of time.

Furthermore, for example, the body movement detecting unit **26** can be disposed in an image processing apparatus other than the PET apparatus **100**. In that case, for example, the image processing apparatus includes a coincidence counting information storing unit that is used to store a time series list of coincidence counting information; a body movement detecting unit that detects the temporal changes in the body movement of the subject based on the time series list of coincidence counting information; and an image reconstructing unit that refers to the temporal changes in the body movement of the subject and accordingly reconstructs images of the subject from the time series list of coincidence counting information. Meanwhile, the temporal changes in the body movement of the subject can be used for purposes other than image reconstruction. In that case, the image reconstructing unit becomes redundant.

According to the positron emission computed tomography apparatus and the image processing apparatus thereof of at least one of the above-described embodiments, body movement information of a subject can be obtained without difficulty.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A positron emission computed tomography apparatus comprising:

a detector configured to detect annihilation radiations released from a subject;

a coincidence counting information generating unit configured to, from a counting information list that is generated from output signals of the detector, search for sets of counting information which counted a pair of annihilation radiations at substantially the same time, generate a set of coincidence counting information for each retrieved set of counting information, and generate a time series list of coincidence counting information;

a body movement detecting unit configured to, from each set of coincidence counting information included in the time series list of coincidence counting information, calculate each pair annihilation coordinate on a line of response (LOR) and detect temporal changes in the body movement of the subject based on a plurality of pair annihilation coordinates that is calculated; and

an image reconstructing unit configured to partition the time series list of coincidence counting information into a plurality of phases based on the temporal changes in the body movement of the subject detected by the body movement detecting unit, and reconstruct an image of each phase by referring to the coincidence counting information included in each phase, wherein

the body movement detecting unit partitions the time series list of coincidence counting information at predetermined time intervals, calculates, at each of the predetermined time intervals, center of gravity coordinates of pair annihilation coordinates that are calculated from coincidence counting information included in the time interval, identifies a direction having the largest temporal changes of the center of gravity coordinates, and detects temporal changes in the body movement of the subject based on temporal changes of the center of gravity coordinates in the identified direction.

2. The positron emission computed tomography apparatus according to claim 1, wherein the body movement detecting unit either calculates an average in each time interval or a standard deviation in each time interval.

3. A positron emission computed tomography apparatus comprising:

a detector configured to detect annihilation radiations released from a subject;

a coincidence counting information generating unit configured to, from a counting information list that is generated from output signals of the detector, search for sets of counting information which counted a pair of annihilation radiations at substantially the same time, generate a set of coincidence counting information for each retrieved set of counting information, and generate a time series list of coincidence counting information;

a body movement detecting unit configured to, from the time series list of coincidence counting information, select a plurality of sets of coincidence information for each of which an LOR passes through a predetermined body part inside the subject, calculate each pair annihilation coordinate on an LOR from each selected set of coincidence counting information, and detect temporal changes in the body movement of the subject based on a plurality of calculated pair annihilation coordinates; and

an image reconstructing unit configured to partition the time series list of coincidence counting information into a plurality of phases based on the temporal changes in the body movement of the subject detected by the body movement detecting unit, and reconstruct an image of each phase by referring to the coincidence counting information included in each phase, wherein,

the body movement detecting unit partitions the time series list of coincidence counting information at predetermined time intervals, calculates, at each of the predetermined time intervals, center of gravity coordinates of pair annihilation coordinates that are calculated from coincidence counting information included in the time interval, identifies a direction having the largest temporal changes of the center of gravity coordinates, and detects temporal changes in the body movement of the subject based on temporal changes of the center of gravity coordinates in the identified direction.

4. The positron emission computed tomography apparatus according to claim 3, wherein the body movement detecting unit either calculates an average in each time interval or a standard deviation in each time interval.

5. A positron emission computed tomography apparatus comprising:

a detector configured to detect annihilation radiations released from a subject;

a coincidence counting information generating unit configured to, from a counting information list that is generated from output signals of the detector, search for sets of counting information which counted a pair of annihilation radiations at substantially the same time, generate a set of coincidence counting information for each retrieved set of counting information, and generate a time series list of coincidence counting information;

a body movement detecting unit configured to, from the time series list of coincidence counting information, select a plurality of sets of coincidence information for each of which an LOR does not pass through a predetermined body part inside the subject, calculate each pair annihilation coordinate on an LOR from each selected set of coincidence counting information, and detect temporal changes in the body movement of the subject based on a plurality of calculated pair annihilation coordinates; and

an image reconstructing unit configured to partition the time series list of coincidence counting information into a plurality of phases based on the temporal changes in the body movement of the subject detected by the body movement detecting unit, and reconstruct an image of each phase by referring to the coincidence counting information included in each phase, wherein,

the body movement detecting unit partitions the time series list of coincidence counting information at predetermined time intervals, calculates, at each of the predetermined time intervals, center of gravity coordinates of pair annihilation coordinates that are calculated from coincidence counting information included in the time interval, identifies a direction having the largest temporal changes of the center of gravity coordinates, and detects temporal changes in the body movement of the subject based on temporal changes of the center of gravity coordinates in the identified direction.

6. The positron emission computed tomography apparatus according to claim 5, wherein the body movement detecting unit either calculates an average in each time interval or a standard deviation in each time interval.

7. An image processing apparatus comprising:

a coincidence counting information storing unit configured to store a time series list of coincidence counting information which represents sets of counting information that substantially concurrently counted a pair of annihilation radiations released from a subject;

a body movement detecting unit configured to from each set of coincidence counting information included in the time series list of coincidence counting information, calculate each pair annihilation coordinate on a line of response (LOR) and detect temporal changes in the body movement of the subject based on a plurality of pair annihilation coordinates that is calculated; and

an image reconstructing unit configured to partition the time series list of coincidence counting information into a plurality of phases based on the temporal changes in the body movement of the subject detected by the body movement detecting unit, and reconstruct an image of the each phase by referring to the coincidence counting information included in each phase, wherein

the body movement detecting unit partitions the time series list of coincidence counting information at predetermined time intervals, calculates, at each of the predetermined time intervals, center of gravity coordinates of pair annihilation coordinates that are calculated from coincidence counting information included in the time interval, identifies a direction having the largest temporal changes of the center of gravity coordinates, and detects temporal changes in the body movement of the subject based on temporal changes of the center of gravity coordinates in the identified direction.

8. An image processing apparatus comprising:

a coincidence counting information storing unit configured to store a time series list of coincidence counting information which represents sets of counting information that substantially concurrently counted a pair of annihilation radiations released from a subject;

a body movement detecting unit configured to, from the time series list of coincidence counting information, select a plurality of sets of coincidence information for each of which an LOR passes through a predetermined body part inside the subject, calculate each pair annihilation coordinate on an LOR from each selected set of coincidence counting information, and detect temporal changes in the body movement of the subject based on a plurality of calculated pair annihilation coordinates; and

an image reconstructing unit configured to partition the time series list of coincidence counting information into a plurality of phases based on the temporal changes in the body movement of the subject detected by the body movement detecting unit, and reconstruct an image of the each phase by referring to the coincidence counting information included in each phase, wherein

the body movement detecting unit partitions the time series list of coincidence counting information at predetermined time intervals, calculates, at each of the predetermined time intervals, center of gravity coordinates of pair annihilation coordinates that are calculated from coincidence counting information included in the time interval, identifies a direction having the largest temporal changes of the center of gravity coordinates, and detects temporal changes in the body movement of the subject based on temporal changes of the center of gravity coordinates in the identified direction.

9. An image processing apparatus comprising:

a coincidence counting information storing unit configured to store a time series list of coincidence counting information which represents sets of counting information that substantially concurrently counted a pair of annihilation radiations released from a subject;

a body movement detecting unit configured to, from the time series list of coincidence counting information, select a plurality of sets of coincidence information for each of which an LOR does not pass through a predetermined body part inside the subject, calculate each pair annihilation coordinate on an LOR from each selected set of coincidence counting information, and detect temporal changes in the body movement of the subject based on a plurality of calculated pair annihilation coordinates; and

an image reconstructing unit configured to partition the time series list of coincidence counting information into a plurality of phases based on the temporal changes in the body movement of the subject detected by the body movement detecting unit, and reconstruct an image of the each phase by referring to the coincidence counting information included in each phase, wherein

the body movement detecting unit partitions the time series list of coincidence counting information at predetermined time intervals, calculates, at each of the predetermined time intervals, center of gravity coordinates of pair annihilation coordinates that are calculated from coincidence counting information included in the time interval, identifies a direction having the largest temporal changes of the center of gravity coordinates, and detects temporal changes in the body movement of the subject based on temporal changes of the center of gravity coordinates in the identified direction.

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